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HIGH STRENGTH AIR BAG QUALITY STEEL

Field of the Invention

This application is a continuation-in-part of pending application Serial No. 09/310,810, filed May 12, 1999, assigned to the assignee of the present invention.

The present invention relates to a process for manufacturing a steel housing, and particularly relates to a process for manufacturing a steel housing of an inflator for inflating an inflatable vehicle occupant protection device.

Background of the Invention

An inflator for inflating an inflatable vehicle occupant protection device includes a quantity of a stored gas and a body of combustible material stored in an inflator housing. An igniter is actuatable to ignite the body of combustible material. As the body

of combustible material burns, the combustion products heat the stored gas. The heated stored gas and the combustion products form an inflation fluid for inflating the vehicle occupant protection device. Another inflator includes a stored inert gas and a stored combustible gas, such as hydrogen. An igniter ignites the combustible gas which heats the stored inert gas.

Summary of the Invention

The present invention is a process for manufacturing a steel sheet, which may be used in an inflator housing. In the process, a slug of steel is provided which is selected from the group consisting of austenitic 301 steel and austenitic 301N steel. The thickness of the slug is reduced by passing the slug through a hot rolling mill while the slug is at a temperature between about 1000°C and about 1200°C, until the slug is formed into a steel sheet. The steel sheet is quenched to lower the temperature of the steel sheet after the steel sheet is hot rolled. The thickness of the steel sheet is further reduced by passing the steel sheet in multiple passes through a cold rolling mill. The steel sheet is reduced in thickness between about

3% and about 13% in the last of its passes through the cold rolling mill.

Preferably, the austenitic 301 steel consists essentially of by weight less than about 0.03% carbon, less than about 2.00% manganese, less than about 0.005% sulfur, less than about 0.030% phosphorous, less than about 1.00% silicon, between about 16.00% and about 18.00% chromium, between about 6.00% and about 8.00% nickel, less than about 0.025% residual elements, and balance iron, and the austenitic 301N steel consists essentially of by weight less than about 0.03% carbon, less than about 2.00% manganese, less than about 0.005% sulfur, less than about 0.030% phosphorous, less than about 1.00% silicon, less than about 0.30% nitrogen, between about 16.00% and about 18.00% chromium, between about 6.00% and about 8.00% nickel, less than about 0.025% residual elements, and balance iron.

Brief Description of the Drawings

The foregoing and other features of the present invention will become more apparent to one skilled in the art upon consideration of the following description of the invention and the accompanying drawings in which:

Fig. 1 is a schematic view of a vehicle occupant protection apparatus embodying the present invention;

Fig. 2 is a sectional view of part of the apparatus of Fig. 1; and

Fig. 3 is a schematic block diagram illustrating a preferred embodiment of the present invention.

Description of Preferred Embodiment

Referring to Fig. 1, a vehicle occupant protection apparatus 10 includes an inflatable vehicle occupant protection device 12. In the preferred embodiment of the present invention, the inflatable vehicle occupant protection device 12 is an air bag. The inflatable vehicle occupant protection device 12 could be, for example, an inflatable seat belt, an inflatable knee bolster, an inflatable head liner an inflatable side curtain, or a knee bolster operated by an air bag.

An inflator 14 is associated with the vehicle occupant protection device 12. The inflator 14 is actuatable to direct inflation fluid to the inflatable vehicle occupant protection device 12 to inflate the inflatable vehicle occupant protection device 12.

The system also includes a crash sensor 16. The crash sensor 16 is a known device that senses a vehicle condition, such as vehicle deceleration, indicative of

a collision. The crash sensor 16 measures the magnitude and the duration of the deceleration. If the magnitude and duration of the deceleration meet predetermined threshold levels, the crash sensor either transmits a signal or causes a signal to be transmitted to actuate the inflator 14. The inflatable vehicle occupant protection device 12 is then inflated and extends into the occupant compartment of the vehicle to help protect a vehicle occupant from a forceful impact with parts of the vehicle.

While the inflator 14 could be a pyrotechnic inflator (not shown), in the preferred embodiment of the invention, the inflator 14 is a stored gas inflator in accordance with the invention set forth in U.S. Patent No. 5,348,344, to Blumenthal et al., entitled APPARATUS FOR INFLATING A VEHICLE OCCUPANT RESTRAINT USING A MIXTURE OF GASES, and assigned to TRW Vehicle Safety Systems Inc.

As shown in Fig. 2, the inflator 14 includes a housing 18. The housing 18 includes a container 20. The container 20 includes a generally cylindrical side wall 24 extending along a central axis 26 between an open end 30 and a closed end 28. The side wall 24

includes a cylindrical inner surface 32 and a cylindrical outer surface 34.

The housing 18 further includes an actuatable pyrotechnic igniter 36 secured to the closed end 28 of the housing 18 by any suitable means. The igniter 36 includes an ignitable material (not shown).

The housing 18 also includes an end cap 38 secured to the open end 30 of the container 20 by any suitable means such as a weld. The end cap 38 includes a radially extending first surface 40 and an axially centered cylindrical surface 42. The cylindrical surface 42 of the end wall 38 has a diameter smaller than the diameter of the inner surface 32 of the side wall 24 and extends axially between and connects the first surface 40 of the end cap 38 and a radially extending second surface 44 of the end cap 38. The cylindrical surface 42 defines a passage 31 through the end cap 38.

A burst disk 46 is secured to the first surface 40 of the end cap 38 by any suitable means, such as a weld. The burst disk 46 closes the passage 31. Together the burst disk 46 and the end cap 38 close the open end 30 of the side wall 24 to define a closed chamber 48 in the container 20. The chamber 48 is

defined by the end cap 38, the burst disk 46, and the cylindrical side wall 24.

A supply of gas 50 for inflating the inflatable vehicle occupant protection device 12 is stored in the chamber 48. The stored gas 50 comprises at least one inert gas. The inert gas is preferably nitrogen, argon, or a mixture of nitrogen and argon.

The stored gas 50 may also include an oxidizer gas and a fuel gas. A preferred oxidizer gas is oxygen. Preferred fuel gases include hydrogen, nitrous oxide, and/or methane. The stored gas 50 may comprise air and hydrogen.

Preferably, the stored gas 50 includes at least a small amount of a tracer gas, such as helium, for helping to detect gas leaks.

The stored gas 50 within the container 48 is under pressure. The pressure depends upon such factors as the volume of the inflatable vehicle occupant protection device 12 to be inflated, the time available for inflation, the inflation pressure desired, and the volume of the chamber 48 storing the gas. The stored gas 50 in the chamber 48 is typically at a pressure of about 2,000 to about 8,000 pounds per square inch

(psi). Preferably, the stored gas 50 in the chamber 48 is at a pressure of about 3,500 psi to about 6,500 psi.

A diffuser 52 is connected to the second surface 44 of the end cap 38 by any suitable means, such as a weld. The diffuser 52 includes a cylindrical side wall 54 coaxial with the side wall 24 of the container 20 and centered on the axis 26. The side wall 54 includes a cylindrical inner surface 56 and cylindrical outer surface 58. The diffuser has a central chamber 60. The chamber 60 is in fluid communication with the passage 31 in the end cap 38.

Fig. 3 is a schematic illustration of a method of producing the housing 18 of the inflator 14. In the method, first and second slugs of steel are provided. The steel used to form the first and second slugs of steel can be either an austenitic 301 steel or an austenitic 301N steel. The composition of the austenitic 301 steel and the austenitic 301N steel are preferably controlled. By "controlled" it is meant that the ranges for the chemical composition of the austenitic 301 steel and the autstenitic 301N steel are more restricted than the ranges for the chemical composition of typical austenitic 301 steel and autstenitic 301N steel.

Preferably, the austenitic 301 steel employed in the present invention consists essentially of by weight less than about 0.03% carbon, less than about 2.00% manganese, less than about 0.005% sulfur, less than about 0.030% phosphorous, less than about 1.00% silicon, between about 16.00% and about 18.00% chromium, between about 6.00% and about 8.00% nickel, and less than about 0.025% residual elements. The balance of the composition is iron. By residual elements, it is meant additional elements including titanium, lead, niobium, cobalt, aluminum, calcium, and/or tin.

Preferably, the austenitic 301N steel employed in the present invention consists essentially of by weight less than about 0.03% carbon, less than about 2.00% manganese, less than about 0.005% sulfur, less than about 0.030% phosphorous, less than about 1.00% silicon, less than about 0.30% nitrogen, between about 16.00% and about 18.00% chromium, between about 6.00% and about 8.00% nickel, and less than about 0.025% residual elements. The balance of the composition is iron. By residual elements, it is meant additional elements including titanium, lead, niobium, cobalt, aluminum, calcium, and/or tin.

The first and second slugs of steel each have a thickness. The thickness of the first and second slug can be the same or different. Preferably, the first and second slugs of steel each have a thickness of about 6.0 inches to about 7.5 inches. More preferably, the first and second slugs of steel each have a thickness of about 7.0 inches.

The first and second slugs of steel are mechanically treated to form first and second steel sheets. The first and second slugs of steel are mechanically treated by hot rolling the first and second slugs of steel. Hot rolling involves passing a product of steel, such as a slug, that has been heated through a rolling mill to substantially reduce the thickness and increase the length and width of the product. A rolling mill typically has two rolls revolving at the same peripheral speed and in opposite directions about their respective axes, i.e. clockwise and counterclockwise. The rolls are spaced so that the distance between the rolls is somewhat less than the thickness of the product of steel passing between the rolls. Under these conditions, the rolls grip the product of steel and deliver it reduced in thickness and increased in width and length.

In the present invention, the first and second slugs of steel are heated to a temperature of about 1000°C to about 1200°C and, while at a temperature of about 1000°C to about 1200°C, the first and second slugs of steel are passed through the rolling mill. Preferably, the first and second slugs of steel are heated to a temperature of about 1100°C and, while at a temperature of about 1100°C, the first and second slugs of steel are passed through the rolling mill.

The first and second slugs of steel are passed through the rolling mill at least once to reduce the thickness of the first and second slugs of steel. The first and second slugs of steel may be reduced in thickness by multiple passes through the rolling mill, with each pass slightly reducing the thickness of the first and second slugs of steel.

Two steel sheets are formed as a result of hot rolling the first and second slugs of steel. The steel sheets have thicknesses, which are substantially less than the thickness of the first and second slugs of steel. The thickness of each of the steel sheets is uniform across the area of each of the steel sheets. One of the steel sheets preferably has a thickness of about 0.155 inches to about 0.165 inches. More

preferably, one of the steel sheets has a thickness of about 0.160 inches. The other steel sheet preferably has a thickness of about 0.090 inches to about 0.110 inches. More preferably, the other steel sheet has a thickness of about 0.100 inches.

After hot rolling, the one steel sheet and the other steel sheet are quenched by a high pressure water spray to reduce the temperature of the one steel sheet and the other steel sheet to room temperature, i.e. about 22°C.

Once the one steel sheet and the other steel sheet are at room temperature, the one steel sheet and the other steel sheet may be pickled in an acidic solution to remove any scale or oxides formed on the surface of the one steel sheet and the other steel sheet during hot rolling. Suitable pickling solutions may include sulfuric acid, phosphoric acid, nitric acid, hydrochloric acid and combinations thereof.

The one steel sheet is then further reduced in thickness by cold rolling the one steel sheet to a first uniform thickness across the area of the one steel sheet. The other steel sheet is reduced in thickness by cold rolling the other steel sheet to a

second uniform thickness across the area of the other steel sheet.

Cold rolling is similar to hot rolling except that the product of steel being rolled is unheated when it passes through the rolling mill. The cold rolling process substantially reduces the thickness of the product being cold rolled and removes small surface imperfections in the surface of the product, which are formed by hot rolling the product. By "substantially reduces the thickness" it is meant the thickness of the product of steel is reduced by greater than 2 percent. This reduction in thickness is distinguished from the reduction thickness typically encountered by temper rolling. Temper rolling, which is similar to cold rolling, usually results in a reduction of thickness of 1 to 2 percent.

The steel sheets of the present invention may be lubricated with an oil based or water based emulsion prior to cold rolling in order to reduce the heat generated by friction as the steel sheet passes between the rolls.

In the present invention, the one steel sheet and the other steel sheet are reduced in thickness by multiple passes through the cold rolling mill. Each

pass slightly reduces the thickness of each steel sheet until the one sheet reaches the first uniform thickness and the other sheet reaches the second uniform thickness. The first thickness is preferably about 0.072 inches to about 0.090 inches. More preferably, the first thickness is about 0.079 inches to about 0.080 inches. The second thickness is preferably about 0.043 inches to about 0.053 inches. More preferably, the second thickness is about 0.048 inches.

The one steel sheet is reduced in thickness about 3% to about 13% during the last pass of the one steel sheet through the cold rolling mill. Preferably, the one steel sheet is reduced in thickness between about 5% and about 13% during the last of the passes through the cold rolling mill, and more preferably about 12% to about 13% during the last of the passes through the cold rolling mill. The other steel sheet is reduced in thickness less than about 50% during the last pass of the other steel sheet through the cold rolling mill.

The other steel sheet with the second thickness is then annealed. Annealing improves the mechanical properties of the other steel sheet. Preferably the other steel sheet is annealed at a temperature of about 1050°C for one and a half minutes in a furnace with air

atmosphere. After being annealed, the other steel sheet with the second thickness is cooled to room temperature (i.e. about 22°C) and deep drawn into the shape of the container 20 using a mechanical press.

The one steel sheet, after cold rolling, is formed into the endcap 38, without being annealed. The one steel sheet is not annealed after cold rolling because the mechanical properties of the one steel sheet are effective for use as an endcap. For example, the one steel sheet formed from austenitic 301 steel formulated in accordance with the present invention has a tensile strength of at least about 90,000 psi, a yield strength of at least about 30,000 psi, and an elongation at break of at least about 30%. Moreover, the one steel sheet formed from austenitic 301N steel formulated in accordance with the present invention has a tensile strength of at least about 95,000 psi, a yield strength of at least about 45,000 psi, and an elongation at break of at least about 40%.

The container 20 and endcap 38 are welded together to form the housing 18 by any suitable means, such as autogenous gas tungsten arc welding, friction, electron beam welding, or laser welding. Preferably, the

container and the endcap are welded together by laser welding.

The housing 18 so formed exhibits outstanding mechanical properties including no stress corrosion cracking in the welded portion of the housing 18, which includes the weld and the base material of the endcap 38 and the container 20 adjacent to the weld. Further, the housing 18 showed no evidence of hydrogen embrittlement in the welded portion.

Example 1

A housing for a vehicle occupant protection device was assembled from an endcap and a container formed in accordance with the present invention.

The endcap was formed by providing a first slug of austenitic 301 steel. The first slug of steel had a thickness of about 7.0 inches. The first slug of austentic 301 steel consisted essentially of by weight less than about 0.03% carbon, less than about 2.00% manganese, less than about 0.005% sulfur, less than about 0.030% phosphorous, less than about 1.00% silicon, between about 16.00% and about 18.00% chromium, between about 6.00% and about 8.00% nickel, and less than about 0.025% residual elements. The balance of the composition is iron. By residual

elements, it is meant additional elements including titanium, lead, niobium, cobalt, aluminum, calcium, and/or tin.

The first slug of steel was heated to a temperature of about 1100°C, and while at a temperature of about 1100°C passed through a rolling mill to produce a first steel sheet with a uniform thickness across the area of the first steel sheet of about 0.160 inches. The first steel sheet was cooled to room temperature (i.e., about 22°C), by quenching with a high pressure water spray. Following quenching the first steel sheet was pickled to remove any scale. The first steel sheet was then reduced to a uniform thickness of about 0.079 inches by multiple passes of the first steel sheet through a cold rolling mill. The last of the passes through the cold rolling mill reduced the steel sheet's thickness by 12.36% (i.e., from a thickness of about 0.089 inches to a thickness of about 0.079 inches).

Samples of the first steel sheet were tested in accordance with ASTM E8/E8M and DIN/EN 10002. The first steel sheet had a had mean yield strength of at least about 101,000 psi, a mean tensile strength of about 140,000 psi, and a mean elongation of about 32%

The steel sheet was then stamped to form the endcap.

The container was formed by providing a second slug of austenitic 301 steel. The second slug of steel had a thickness of about 7.0 inches. The composition of the second slug of austenitic 301 steel was essentially the same as the composition of the first slug used to form the end cap. The second slug of steel was heated to a temperature of about 1100°C, and while at a temperature of about 1100°C passed through a rolling mill to produce a second steel sheet with a uniform thickness across the area of the steel sheet of about 0.100 inches. The second steel sheet was cooled to room temperature (i.e., about 22°C) by quenching with a high pressure water spray and then pickled to remove any scale. The second steel sheet was then reduced to a uniform thickness of about 0.048 inches by multiple pass of the second steel sheet through the cold rolling mill. The last of the passes through the cold rolling mill reduced the second steel sheet's thickness by less than 50%. The second steel sheet was annealed at a temperature of about 1050°C for about one minute and a half in an air atmosphere. After being annealed the

second steel sheet was deep drawn into the shape of the container using a mechanical press.

The endcap and the container were then welded together by laser welding to form a housing.

A c-ring type specimen was removed from a welded portion of the housing 18 and placed in a 3% NaCl saturated air atmosphere. The c-ring type specimen was maintained at a temperature of about 25°C and subjected to a voltage of about 1.5V from a Ag/AgCl hydrogen cathode charging mechanism. Stress equivalent to 100% of the actual yield strength was applied to the c-ring type specimen for one month.

Analysis by thermal absorption spectrometry and scanning electron microscopy revealed no evidence of hydrogen embrittlement in the welded portion or base metal surrounding the welded portion of the c-ring type specimen after the one month period.

Moreover, a c-ring type specimen was removed from a welded portion of the housing and placed in a 3% NaCl saturated air atmosphere at a temperature of about 80°C. Stress equivalent to about 100% of the actual yield strength was applied to the c-ring type specimen for one month.

Analysis by thermal absorption spectrometry and scanning electron microscopy revealed no evidence of stress corrosion cracking in the welded portion or base metal surrounding the welded portion of the c-ring type specimen after the one month period.

Comparative Examples 1-3

Three housings for vehicle occupant protection devices were assembled from containers and endcaps. The containers of the comparative examples were formed by the same process used to form the container of example 1. The endcaps were formed by essentially the same process as the process used to form the endcap of example 1. The only difference between the process used to form the endcap of the comparative examples and the process used to form the endcap of example 1, was the percent that each steel sheet of the comparative examples was reduced during the last pass of each steel sheet through the cold rolling mill.

The steel sheet of comparative example 1 was reduced from a thickness of about 0.099 inches to about 0.079 inches (i.e., about 20%) during the last pass through the cold rolling mill. The steel sheet of comparative example 2 was reduced from a thickness of about 0.095 inches to about 0.078 inches (i.e., about

17.8%) during the last pass through the cold rolling mill. The steel sheet of comparative example 3 was reduced from a thickness of about 0.091 inches to about 0.079 inches (i.e., about 13.1%) during the last pass through the cold rolling mill.

Each of the endcaps so formed was then laser welded to a container to form a housing.

A c-ring type specimen was removed from a welded portion of each of the housings of the comparative examples and placed in 3% NaCl saturated air atmosphere. The c-ring type specimens were maintained at a temperature of about 25°C and subjected to a voltage of about 1.5V from a Ag/AgCl hydrogen cathode charging mechanism. Stress equivalent to 100% of the actual yield strength was applied to the c-ring type specimens for one month.

Analysis by thermal absorption spectrometry and scanning electron microscopy revealed hydrogen embrittlement in the welded portion or base metal surrounding the welded portion of the c-ring type specimens after the one month period.

Moreover, a c-ring type specimen was removed from each of the welded portions of the housing and placed in a 3% NaCl saturated air atmosphere at a temperature

of about 80°C. Stress equivalent to about 100% of the actual yield strength was applied to the c-ring type specimens for one month.

Analysis by thermal absorption spectrometry and scanning electron microscopy showed evidence of stress corrosion cracking in the welded portion or base metal surrounding the welded portion of the c-ring type specimens after the one month period.

Advantages of the present invention should now be apparent. Primarily, the present invention takes advantage of the improved mechanical properties of a housing 18 manufactured from austenitic 301 or austenitic 301N steel of which the composition has been controlled and which has been mechanically treated by controlled hot rolling and cold rolling of the steel. The housing 18 exhibits no evidence of stress corrosion cracking along the weld between the housing components. Furthermore, there is no evidence of stress corrosion cracking of the portion of the housing components adjacent to the weld. Moreover, austenitic 301 steel and austenitic 301N steel with the composition of the present invention and mechanically treated by the method of the present invention exhibits no hydrogen

embrittlement in the weld or portions of the housing components adjacent to the weld.

From the above description of the invention, those skilled in the art will perceive improvements, changes and modifications. Such improvements, changes and modifications within the skill of the art are intended to be covered by the appended claims.